

Forecasting the onset date of southwest monsoon over Delhi

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(Received 18 April 1996, Modified 1 August 1997)

सार — पिछले 32 वर्षों (1964-95) के आँकड़ों का प्रयोग करते हुए, अप्रैल और मई के मानसून पर्व महीनों के विविध समदाब रेखीय मानक स्तरों (850 से 10 हैक्टोपास्कल) के चुने हुए विभिन्न केन्द्रों के वायु के उपरितन वायु तापमान और वायु के क्षेत्रीय तथा दक्षिणीय घटकों की जाँच की गई है। जिससे दिल्ली में दक्षिण- पश्चिम मानसून के आगमन की तिथि के साथ उनके संबंध के विषय में अध्ययन किया जा सके। विभिन्न केन्द्रों के मई माह के तापमान और वायु-घटकों के आँकड़े मानसून की आगमन तिथि के साथ महत्वपूर्ण सहसंबंध दर्शाते हैं। मानसून की मौसमी वर्षा के दीर्घावधि पूर्वानुमान मॉडलों में वर्तमान में प्रयोग होने वाले कुछ प्रमुख प्राचलों की भी इसी तरह जाँच की गई है। महत्वपूर्ण रेखिक सहसंबंध दर्शाने वाले उपर्युक्त प्राचलों के उपयोग से बहु- समाश्रयण तकनीक द्वारा समीकरणों का विकास किया गया है।

ABSTRACT. Using latest 32 years (1964-95) data, upper air temperatures and zonal and meridional components of winds of several selected stations for various standard isobaric levels (850 to 10 hPa) are screened for the premonsoon months of April & May in order to study their association with onset date of southwest monsoon at Delhi. Data for temperature and wind components for May for several stations exhibit significant correlations with onset-date. Some well known parameters presently in use in long range forecast models of monsoon seasonal rainfall have also been screened similarly. With a multiple regression technique, equations have been developed using suitable parameters from those which showed significant linear correlations.

Key words- Onset dates, Screening, Correlations, Long range forecast, Regression technique, Forecast models.

1. Introduction

Southwest monsoon progresses over India, generally, in a direction from south to north in the peninsular and central India and from east to west over northern parts of the country. The onset date for Kerala, the southernmost state of India, is 1 June. In its northward travel from Kerala to Delhi, on an average it takes about 4 weeks. But, there are wide variations to this travel time in different years.

India Meteorological Department (IMD) has fixed criterion for declaration of onset date of monsoon for Kerala. Onset date at other places is basically the date of actual commencement of persistent rainfall, which is characteristic of the monsoon at that place. The publication (IMD 1943) giving the normal dates of onset states that the onset dates have been derived from five day normals of accumulated rainfall published by IMD. It further states that diagrams were prepared showing the normal rainfall at each reporting station for successive five-day periods in the year. The middle date of the five-day period, showing the characteristic rise in the monsoon rainfall curve, was taken as the date of onset of the monsoon at that place. At stations where

thunderstorm rains merge into the monsoon rain, and the transition is gradual, other factors have also been taken into consideration. Thus the above definition leaves some scope for subjectivity. Various research scientists have used different but related criteria based on pentad rainfall, kinetic energy, transition from light to heavy rain spell category etc. to define the onset. There is bound to be a difference in the onset dates fixed operationally by IMD and by the research scientists. There is sometimes scope for a difference of opinion even amongst operational meteorologists. Because of this inherent subjectivity in fixing the date of onset of monsoon, one cannot expect a perfect onset data and this militates against development of dependable forecasting formulae for onset date.

Gupta and Ali (1985) have studied the monthly mean wind and temperature data at 300 and 200 hPa for the month of April for the stations Thiruvananthapuram, Madras (Chennai), Bombay(Mumbai), Nagpur, Ahmedabad, Jodhpur and New Delhi in association with the onset of southwest monsoon over Delhi. They have concluded that northerly mean meridional component of wind at 300 hPa over Mumbai in April is favourable for early onset of

monsoon over Kerala and that Nagpur is colder than Mumbai at 300 and 200 hPa in April in the years of early onset, while it is warmer than Mumbai at these two levels in the years of late onset over Delhi.

The study of Ananthkrishnan and Thiruvengadathan (1968) has revealed that the winter westerly circulation is strong at Delhi and continues till the end of May. By the beginning of June, the thermal gradient reverses at 200 hPa and at the same time, the westerly circulation weakens considerably at all the lower levels. Thereafter, the vertical shears and thermal gradients are generally feeble. By the first week of July, the temperature gradients reverse at all levels above 700 hPa, and by that time the monsoon rains extend to Delhi.

It is reasonable to assume that the change-over from winter to monsoon circulation is a continuous process in the broader sense. To monitor the change, time averages of greater than 10 days may be considered to be free from effects of travelling short waves. Such averages, during late premonsoon period, can be expected to be related to the onset date of monsoon for Delhi. The data of May is expected to be better than that of April in view of formers' closeness to monsoon season. In fact, as per the study of Ananthkrishnan and Thiruvengadathan (1968) data of June should be more appropriate. But, 10-day averages or daily data for June are not readily available and entire June months' average cannot be used as the forecast has to have some lead time. Therefore, the authors have used the May data.

All the above referred studies connected with forecast of onset date are of qualitative nature, therefore, they do not meet the requirement of forecaster. Only a few efforts have been made so far to develop regression equations for forecasting onset dates. Nevertheless, work of Kung *et al.* (1980, 1982) is worth mentioning for onset over Kerala.

The standard deviation (SD) of onset date for various locations in India ranges from 7 to 10 days. For Delhi, the SD is 8.4 days (Chowdhury *et al.* 1990) and it is still larger for locations in Rajasthan and Gujarat. As per the dates for earliest and delayed onset mentioned by Chowdhury *et al.* (1990), it is seen that there is a difference of about 6 weeks between the earliest declared onset dates and most delayed onset dates over northwest India. The largeness of this period highlights the urgent need of some objective method to forecast the onset date over this region.

2. Data

The data for onset dates of Delhi has been taken from the official records of IMD. The data representing the date of onset are computed by counting from 1 May upto the onset date. With this convention, the onset on 29 June is represented by the number 60 and onset on 3 July is represented by the number 64 and so on.

The authors have utilised the upper air wind and temperature data of all available stations in India and have confined the period of study to 1964 onwards. Monthly mean data for upper air elements have been obtained from various sources as follows:

- (i) 1965-88 : Means for temperature and upper air winds were computed from daily data for April and May received from IMD, Pune.
- (ii) 1964 : Monthly Climate Data for the world, Published by NOAA.
- (iii) 1989-92 : Monthly Climate Data published by IMD, New Delhi.
- (iv) 1993-95 : Operational data set available at IMD, Delhi.

Data for the well known circulation parameters, *i.e.*, Darwin Pressure Tendency (DPT) (April Minus January) computed from Darwin pressure data, Tahiti-Darwin Pressure (TDP) Mar-Apr-May (MAM) minus Dec-Jan-Feb (DJF), Bombay Pressure Tendency (BPT) (MAM minus DJF), Darwin Pressure Tendency (DPT) (MAM minus DJF) computed from Darwin pressure data, heat low pressure over Pakistan and northwest India for the month of May and mean ridge position of 500 hPa in April along 75°E were taken from various sources, mentioned in the literature (Dhanna Singh *et al.* 1995) connected with long range monsoon forecast.

The zonal and meridional components of upper air mean winds for April and May for all standard levels were computed for all stations for which data was available continuously for the entire period. These stations are New Delhi, Calcutta, Mumbai, Guwahati, Thiruvananthapuram, Chennai, Jodhpur, Minicoy, Nagpur and Port Blair.

3. Methodology

Monthly average data series representing some regional and global circulation parameters, which can be used as proxy for the change in the atmospheric circulation from the premonsoon to monsoon type, are used for computing correlation coefficients (CCs) with the data representing onset dates of monsoon over Delhi. Parameters are shortlisted based on significance of their linear correlations for further trial in regression equations. Generally, parameters with CCs significant at 5% or better level only are accepted at this stage. The shortlisted parameters are subjected to multiple regression analysis. In this method the equation is formed using the shortlisted parameters so that the residual errors between the fit and the actual are minimised.

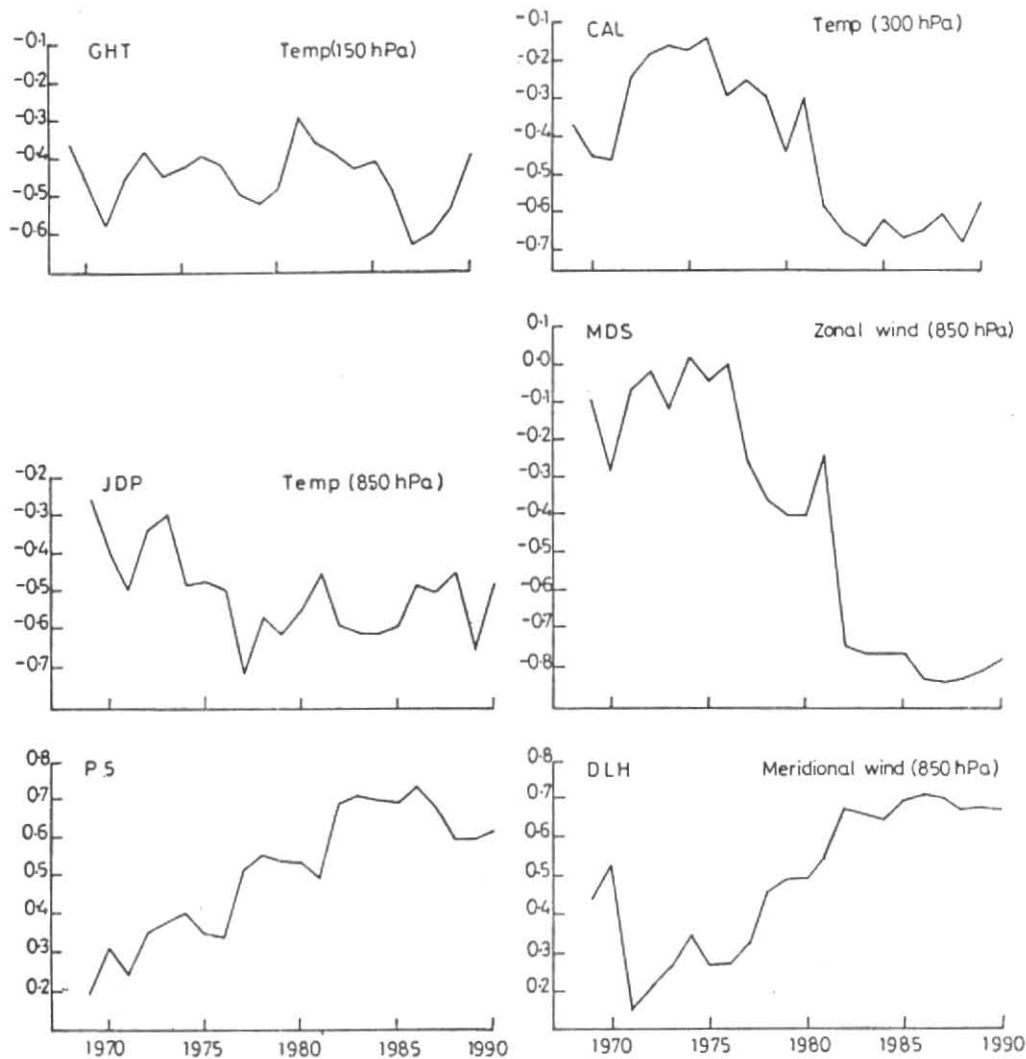


Fig.1. Variation of correlation coefficients of Delhi's onset date with individual parameters for sliding window of 11 years during the period 1964-95. The values are plotted against the middle year of the window

Significance of the individual parameter is seen by the ratio of the partial regression coefficient and the standard error for each parameter. Predictors are arranged in descending value of this ratio and runs are made dropping the parameters from the end till the stage when the dropping of a parameter decreases the variance explained by more than 2%. To quantify the relative importance of the fitted equations, the multiple correlation coefficient (MCC) and the value of Fischer's coefficient are also evaluated and presented.

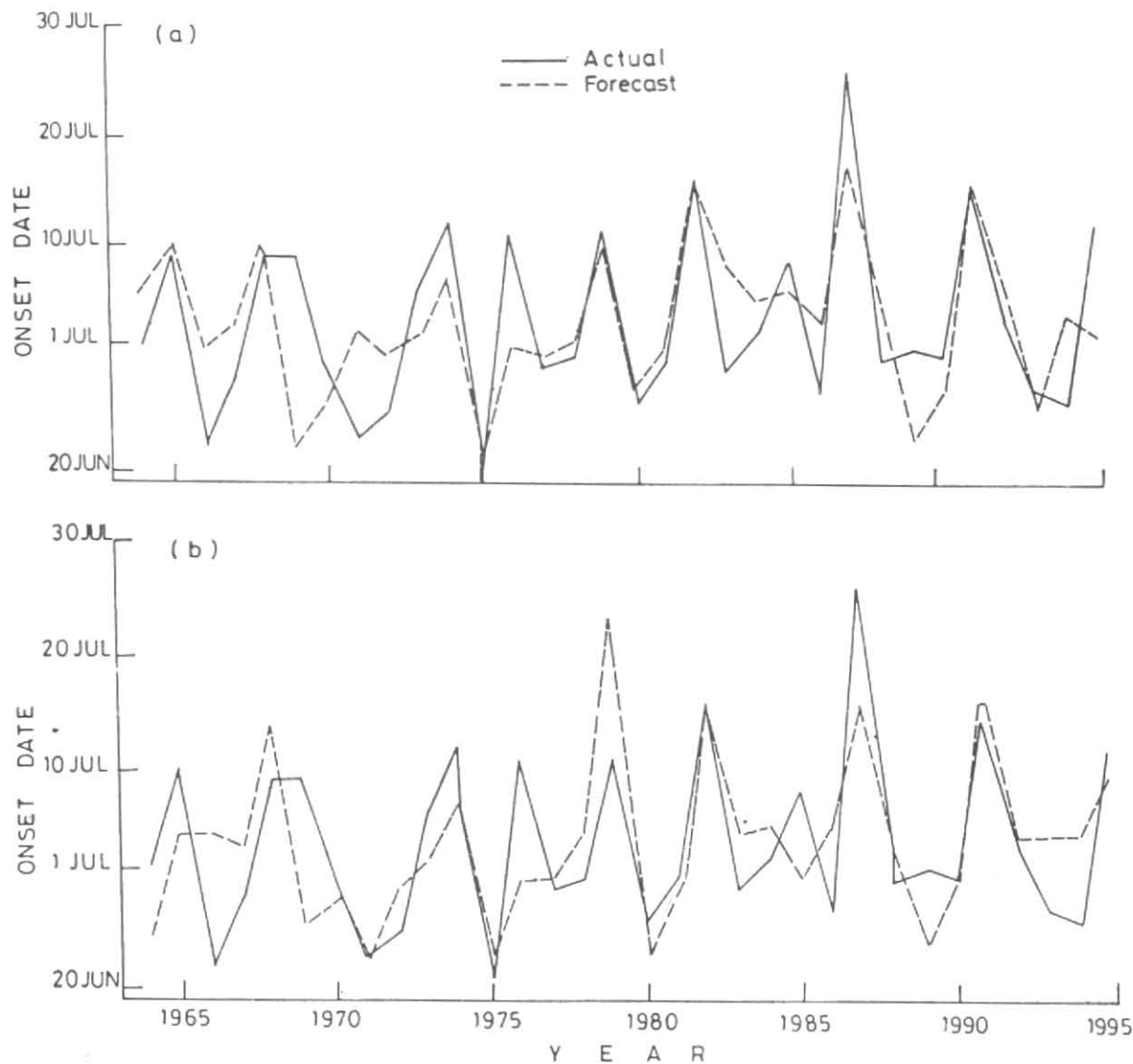
Usefulness of the models have been tested in a realistic way by cross validation over the entire period, *i.e.*, by removing each year in turn for verification while keeping rest of the years for model equation. In this way, the forecast was available for each of the 32 years. The forecast and the

actual dates are displayed graphically in Fig.2. Root mean square of forecast errors have also been computed and compared with standard deviation. Correlation coefficient between the actual dates and the forecast dates have also been computed.

4. Results and discussion

4.1. Correlations

Out of the six well known parameters mentioned in section 2, only the heat low pressure (P5) for May over northwest India and Pakistan showed significant correlation (significant at 1 %). CCs of other parameters were not significant even at 20% level. Even, the Mumbai pressure



Figs.2(a&b). Performance of (a) Model I and (b) Model II

tendency which has very high correlation (parthasarthy *et al.* 1991) with the Indian monsoon rainfall, showed a correlation of nearly zero.

Upper air wind data (zonal and meridional components and temperature) for April exhibit very weak correlations. Thus the results of Gupta and Ali (1985) do not pass the quantitative tests of significance when longer period data is analysed. But, analysis of wind data for May gave promising results. In the description to follow, May month is implied unless stated otherwise while discussing correlations of upper wind and temperature data. CCs of 500 and 300 hPa meridional components of Delhi upper air winds for the

month of May were significant at 5% & 1% levels of significance, respectively. Meridional component for upper tropospheric winds for Guwahati (GHT), Calcutta (CAL), Nagpur (NGP), Madras (MDS) and Thiruvananthapuram (TRV) also show CCs significant at least at 5% level of significance. Correlations for meridional components of their other levels were generally weaker. Out of the zonal components the Thiruvananthapuram, Minicoy (MNC) and Madras (all located south of 15°N lat.) data for 850 hPa for May show correlations significant at least at 5% level of significance. The upper tropospheric meridional components for stations over peninsular India also show correlations significant at 5% or higher level.

The CCs for the upper tropospheric meridional components were positive and those for lower tropospheric zonal components were negative for practically all the stations. These results imply that when westerly component of mean zonal wind of May is stronger in the lower troposphere over south India, the onset over Delhi is early. In case of upper troposphere, stronger southerly component implies delayed onset. Our results based on long period data and on quantitative analysis have proved the importance of wind data of May for forecasting onset date of Delhi in comparison to data of April. Better utility of May data compared to April data is, in fact, implied by the study of Ananthakrishnan and Thiruvangadathan (1968).

CCs with May temperatures of standard isobaric levels of all the stations (13), for which complete data were available, gave even more interesting results. The CCs for peninsular India were not significant at 5% level of significance. The correlations over northern part of the country for the level maximum CCs were generally significant at least at 5% level of significance. The level of maximum CCs for stations over northern India showed a rise (in terms of height) from west (Jodhpur) to east or north. The maximum value of correlation is -0.55 for Delhi for 200 hPa. This is significant at 1% level of significance. The coherence in the correlations for different levels of the same station and same level of different stations justifies the use of the temperature data for the regression analysis. The negative sign of CCs implies that whenever the tropospheric temperatures for May are higher, the onset over Delhi is earlier and vice-versa. This is in conformity with findings of Ananthakrishnan and Thiruvangadathan (1968) as the increasing temperatures over northern part of India are responsible for the reversal of temperature gradients in the troposphere.

Extensive use has been made of the temperature data in the regression equations developed here. Therefore, it was considered necessary to study the temporal stability of the association between upper air temperatures and the onset date over Delhi. For this purpose 11 and 21-year running correlations were computed for the temperature series. Plot for the 11-year correlations is shown in Fig.1. It is seen from the plots that the correlation has changed sign only for one series and that too only for a single period. The correlations are generally better in the latter period of study. The 21 year running correlations, which are not shown for the sake of brevity, were more stable with the individual values ranging between -0.3 and -0.6. These results establish the reasonable stability of the correlations which justify the use of upper air temperatures as parameters in the regression equations for onset date of Delhi.

4.2. Regression equations

Using the multiple regression technique, regression equations were developed using the data for 1964-95. Parameters shortlisted on the basis of 5% level of significance of their linear correlations were used to form multiple linear regression equations. The significance of partial regression coefficients was used to reduce the list of parameters in the equations. Thus, the parameters which were contributing only a little in the equations were dropped. Results of two regression equations are presented in Fig.2. The parameters used in the equations, in the order of significance of their partial regression coefficients for model 1 are:

- x_1 = CAL, 200 hPa temperature
- x_2 = GHT, 150 hPa temperature
- x_3 = GHT, 200 hPa temperature
- x_4 = CAL, 300 hPa temperature
- x_5 = TRV, 850 hPa zonal wind component (mps)
- x_6 = JDP, 850 hPa temperature
- x_7 = BMB, 500 hPa temperature and for model 2 the parameters are:

- x_1 = CAL, 200 hPa temperature
- x_2 = GHT, 150 hPa temperature
- x_3 = GHT, 200 hPa temperature
- x_4 = CAL, 300 hPa temperature
- x_5 = P5
- x_6 = TRV, 850 hPa zonal wind component
- x_7 = MDS, 850 hPa zonal wind component
- x_8 = DLH, 500 hPa meridional wind component

The first five parameters of Eqn.(1) are also available in Eqn.(2) though in a different order.

The two equations for the above mentioned models are:

$$y^* = 4.998 x_1 - 0.484 x_2 + 4.65 x_3 - 0.521 x_4 - 0.261 x_5 - 1.383 x_6 - 2.636 x_7 + 121.3251 \quad (1)$$

$$y^* = 0.4785 x_1 - 0.604 x_2 + 0.495 x_3 - 0.506 x_4 + 0.1814 x_5 - 0.362 x_6 + 0.272 x_7 + 0.082 x_8 - 1777.1287 \quad (2)$$

where, y^* is a number counted from 1 May till the onset date

For verification of these equations forecasts were prepared for each year. These forecasts with the actual onset dates are given in Fig.2. The root-mean square of the difference between the forecast and the actual onset date is 6.0 and 6.21 days respectively. This is of the order of the standard deviation of the onset date. The correlation between the forecast and the actual onset dates is found to be

0.66 for both the equations which explains 44% of variance which is significant at 0.1% level.

As the onset data are based on dates which have an element of subjectivity in their fixation, at least in some of the years, we do not expect a very high multiple correlations or very low root mean square errors (RMSE) for the equations. Another point worth mentioning is the number of parameters used in the equations. Generally smaller number is preferable, but, we have kept slightly larger number so as to compensate for the subjective nature of onset data and to bring the MCC to a reasonably higher value. The second equation with larger number of parameters has MCC of 0.84 compared to 0.8 of the first equation. The first equation does not accommodate the parameter 'Heat Low Pressure' which has the second highest linear correlation amongst the parameters. With the current data (4 years) both the equations have shown equally good results in the test mode.

5. Conclusions

- (i) Many of the well known circulation parameters used for long range monsoon forecast in India do not exhibit significant linear correlation with onset date over Delhi.
- (ii) Pressure in the heat low over Indo-Pak region during May has a significant correlation with the onset date over Delhi.
- (iii) Upper air temperatures during May at different levels of various stations in north India exhibit coherent and significant correlations with onset date over Delhi.
- (iv) Meridional components of average upper air wind data for May has shown significant CCs with the onset date over Delhi. Zonal components for the same month for lower tropospheric wind

data of peninsular India have also shown good correlations.

- (v) Regression equations presented in the paper are reasonably good for trial.

Acknowledgements

The authors are grateful to the Director General of Meteorology for encouragement and thankful to Dr R.R. Kelkar, Additional Director General of Meteorology and Shri B. Lal, Dy. Director General of Meteorology for their keen interest in the study. The authors are also thankful to Shri Khushal Singh and Mrs Chaitali Vasoo for assistance in typing the manuscript and drawing of figures.

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